THE EFFECTS OF PLASTIC AND EGG SHELL WASTE MATERIALS ON THE PHYSICAL AND STRENGTH PROPERTIES OF FLOOR TILES

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Declaration

This thesis is my original work and has not been submitted to any other university for examination.

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Dedication

This thesis is dedicated to my late Aunt Nakabugo Sylvia, my mother Judith, Granny Margret, my wife Evelyn Kyarisiima, my son Semanda Julius Lennon and my daughters Nampijja Patricia and Yvonne Semanda Bibiana.

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Acronyms

HDPE	High density polythene
LDPE	Low density polythene
ASTM	American Standards of Testing Material
UHMWP	High Molecular Weight Polyethylene
USDA	United States Department of Agriculture
FDA	Food and Drug Administration
JKUAT	Jomo Kenyatta University of Agriculture and technology
BEED	Department of Biochemical and Environmental Engineering
OPC	Ordinary Portland cement

Abstract

Human activities often generate solid wastes such as plastics and egg shell wastes. Disposal of these wastes is usually a problem. The aim of this study was to investigate the feasibility of using plastic and egg shell wastes together with white cement in the production of floor tiles. The waste was collected from kitchens and waste disposal facilities within Juja constituency, Kenya. The materials were cleaned and dried; and plastics were shredded while egg shells were crushed. Waste materials were then mixed with white cement in different proportions. Compressive strength tests were carried out to determine the suitability of using such solid wastes in making floor tiles. Crushed egg shells passing through the 1.2 mm sieve and shredded plastics with an average diameter of to 1 to 2 mm were used. Cubes were cast and cured for 28 days. The compressive strength of the cubes was tested using a universal testing machine. The study found that addition of up to 50% cement resulted in more than 10 fold increase in the compressive strength of the cast cubes. Addition of plastics decreased the compressive strength of the cubes while addition of egg shells had insignificant effect on compressive strength. Increasing the quantity of plastics and egg shells resulted in elevated water absorption, while larger quantities of cement resulted in reduced water absorption. Increasing the quantity of egg shells and plastics resulted in reduced density. With the presence of plastics, abrasion resistance increased and the tiles became less brittle. It is concluded that egg shells can be used as filler material in the manufacture of floor tiles. Because of the tendency of plastics to reduce the compressive strength of tiles, they should be used

cautiously. The study has established that use of plastic and egg shell wastes in the manufacture of floor tiles is a viable waste reduction option. However, further studies are necessary to establish the chemical interactions involved in floor tile production systems where household and industrial wastes such as plastics and egg shells are used.

CHAPTER 1: INTRODUCTION AND BACKGROUND

1.1 Introduction

Growth of population, increasing urbanization, and rising standards of living due to technological innovations have contributed to increase in the quantity of a variety of solid wastes generated by industrial, mining, domestic and agricultural activities (Safiuddin et al., 2010). Globally, the estimated quantity of solid wastes generation was 12 billion tons in the year 2002 (Pappu et al., 2007). Many authorities and investigators are lately working to have the privilege of reusing the wastes in environmentally and economically sustainable ways (Aubert et al., 2006). The utilization of solid wastes in construction materials is one of such innovative efforts. Freire and Holanda, (2006) previous study indicated that the egg shell waste samples were rich in $CaCO_3$ (50.7%) and may be used as an alternative raw material in the production of wall tile materials.

Use of floor tiles in construction is for decorative, protection and aesthetic purposes (Kornmann and CTTB, 2007). The core material mostly used to produce floor tiles is clay which may be glazed to improve the tile properties. Fiori and Brusa, (1983), fabricated ceramic tiles in India using blast furnace slag with 0.1–2.5% water absorption.

Tiles have to have a degree of impact resistance. Impact resistance of ceramic tiles is important for their life in service. Floor tiles are expected to sustain many types of loads, some of which may be static but impact loads also occur. Impact loads provide the most usual way for breakages on walls (Harrison and Ralph, 1988).

Effect of water absorption on frost resistance of clay roofing tiles was studied and it was stated that the relationship between the water absorption and frost resistance of brick products cannot be precisely defined. Water absorption capacity identifies the nature of the ceramic body in regard to internal structure, which is related to mechanical strength (measured by modulus of rupture and breaking strength) and also other characteristics that affect ceramic tile durability (particularly in unglazed tiles), such as resistance to deep abrasion, stain resistance, and resistance to frost/thaw cycles, as well as to dimensional quality (Sveda, 2003).

For glazed tiles intended for flooring, European standard EN 14411 makes it compulsory to state the abrasion resistance class of the glazed surface as a whole (glazes and decorations), after performance of the standard test according to ISO 10545-7 (1999). In an effort to eradicate solid waste this study focuses on using solid waste in form of egg shells and plastic as construction raw materials to develop floor building tiles.

1.2 Background

Kampala city has been hit most by the effects of plastic wastes (see Plate 1.1 and Table 1.1). This has led to a lot of unpleasant sceneries in the city. This study aims at investigating the possibility of how plastics can be applied in construction industry as a way to reduce on plastic wastes in Kampala city especially in Kawempe and Rubaga divisions so that to improve on the hygiene in the area. These areas have got a lot of dumping areas and this has resulted into poor hygiene in the area, rampant flooding especially when it rains in places like Bwaise and Kaleerwe. This has been greatly caused by the blocking of water channels by plastics and Egg shell wastes, which are the major components of all the wastes dumped.

Plate 1.1: Plastic trash on an unauthorized dump in Kampala, Uganda, 2011

Despite the attempts that the government has made to ban the use of these bags which constitute a large percentage of the plastics, there has been continued use of this material in Uganda today. Under the Solid Waste Management Ordinance, 2000, it is illegal and punishable to dump garbage in places where it may be or become a public health nuisance. Therefore, there is a need for engineering intervention so as to make use of this material in applications that would reduce on the amounts disposed in the environment.

Waste management in urban centers of East Africa has for a long time been centralized (Liyala 2011), where use is made of the imported refuse trucks (see Plate 1.2) (Rotich et al., 2006; Okot-Okumu & Nyenje 2011) to collect wastes from sources to designated waste dumps. Municipal solid waste management (MSWM) system in East Africa has changed from the colonial days when it was efficient because of the lower population and adequate resources (Okot-Okumu & Nyenje 2011) as compared to the current status that displays inefficiencies. The current waste management system has evolved from centralized to a mixture of decentralized as well as the involvement of the private sector.

Plate 1.2: Waste transportation and disposal (source: Solid Waste Management Ordinance, 2000)

The persistent inadequacies in collection and disposal of waste of waste make it impossible for the institutions to provide any reliable estimates. The storage, collection, transportation and final treatment/disposal of wastes are reported to have become a major problem in urban centers (ADB 2002; Kaseva & Mbuligwe 2005; Okot-Okumu & Nyenje 2011; Rotich *et al.*, 2006). Wastes generated by the East African urban centers are mainly composed of decomposable organic materials (see Table 1.1), (Oberlin, 2011; Okot-Okumu & Nyenje 2011; Scheinberg, 2011; Simon, 2008; Rotich *et al.*, 2006). Efficient collection system to avoid health, aesthetics and environmental impacts is strongly called for.

Table 1.1: Composition of solid wastes generated in East African urban centers (Source: Scheinberg et al., 2010)

Waste Composition (%)	**Dar es salaam**	**Moshi***	**Kampala #+**	**Jinja**	**Lira**	**Nairobi***
Biowaste	71	65	77.2	78.6	68.7	65
Polythene Paper	9	9	8.3	8	5.5	6
Plastic	9	9	9.5	7.9	6.8	12
Glass	4	3	1.3	0.7	1.9	2
Metal	3	2	0.3	0.5	2.2	1
Others	4	12	3.4	4.3	14.9	14
kg/cap/day	0.4	0.9	0.59	0.55	0.5	0.6
Percent collection	40	61	60	55	43	65
Population	3,070,060	183,520	1,700,850	91,153	107,809	4,000,000
Population paying for collection (%of total population)	ND	35	ND	ND	ND	ND

ND= Not determined, + KCC, 2006; #NEMA 2007

As plastics form a significant part of the wastes in the city, an engineering intervention to make use of this material in applications that would reduce on the amounts disposed in the environment is paramount.

Egg shells are waste materials from hatcheries, homes and fast food industries (Phil and Zhihong, 2009; Amu *et al*., 2005) and can be readily collected in plenty. Egg shell waste disposal contributes to environmental pollution. Challenges associated with disposal of Egg shells include cost, availability of disposal sites, odour, flies and abrasiveness (Phil and Zhihong, 2009). However, they can be processed into saleable products like fertilizer, used in artwork, human and animal nutrition and building materials and to produce collagen from the membranes (Phil and Zhihong, 2009; Amu *et al*., 2005). The composition of the Egg shell is approximately 98.2%, 0.9%, 0.9%, calcium carbonate, magnesium and phosphorous (phosphate) respectively (Romanoff *et al*., 1949).Egg shells and shell membranes are non-edible by-products that have little saleable value but may also contain biologically active compounds (Nakano *et al*., 2003).

The chemical composition of the avian Egg shell waste sample shows that calcium oxide (CaO) is the most abundant component (Table 1.2). The high amount of calcium oxide is associated with the presence of calcium carbonate, which is the main component of avian Egg shell. The sample also contained only small amounts of P_2O_5, Na_2O, SrO, SiO_2, MgO, Cl, Al_2O_3, Fe_2O_3, and NiO reporting less than 1.5% of the total composition. Thus, the Egg shell waste sample can be considered from a chemical viewpoint a pure relatively natural carbonate-based material, as well as its composition is very similar to the calcitic calcareous. In addition, it was also observed that the loss on ignition for waste sample was found to be 47.8%. This high value of Loi is caused mainly by decomposition of the calcite with formation of CaO and carbon dioxide (CO_2).

Table 1.2: Composition of egg shell (Source: Freire and Holanda, 2006)

CaO	50.7
SiO_2	0.09
Al_2O_3	0.03
MgO	0.01
Fe_2O_3	0.02
Na_2O	0.19
P_2O_5	0.24
SrO	0.13
NiO	0.001
SO_3	0.57
Cl	0.08
Loi	47.8

Loi = loss on ignition

The results from the study done by Freire and Holanda (2006) indicated that the Egg shell waste sample rich in $CaCO_3$ can be used as an alternative raw material in the production of wall tile materials. The avian Egg shell waste sample studied in this work is chemically constituted basically by calcium oxide (CaO), and is more pure than traditional carbonate based materials used in ceramic industry.

1.3 Problem statement

Solid wastes including Egg shells & plastics, once used and dumped, can accumulate without decomposing resulting in unsightly sceneries, blocking of water movement channels, reduction of soil fertility by preventing moisture penetration into the soils and wide spread of diseases like malaria and cholera as a result of creation of bleeding grounds.. On the other hand, these materials may be useful for the construction industry. The aim of this study was to investigate the feasibility of conserving the environment by collecting such wastes and converting them into floor tiles.

1.4 Research objectives

1.4.1 Main objective

The main objective of this study was to assess the effect of plastic and eggshell waste materials on the physical and mechanical characteristics of floor tiles.

1.4.2 Specific objectives

The specific objectives of the study are to:

1. To determine the optimum proportions of eggshells and plastics required for maximum compressive strength of building tiles.
2. To determine the effect of proportions of Egg shell and plastic waste materials on the physical (density, water absorption) and mechanical characteristics (Surface abrasion, impact resistance) of floor tiles.

1.5 Justification

The wide spread of wastes around Kampala city, the occurrence of flooding especially when it has rained due to the blocking of water movement channels and the wide outbreak of diseases like malaria and cholera due to creation of bleeding grounds for houseflies and stagnant water for mosquitoes, have justified this research to be carried out to find a solution through the construction industry.

1.6 Significance

The research will help in the reduction of the amount of plastics and Egg shells dumping in cities and towns, so that unpleasant sceneries, flooding due to blockage of water movement channels, outbreak of diseases like cholera and malaria together with environmental degradation are reduced.

Manufacturers of plastics as well as poultry farmers will have an alternative market and source of money for their products due to the demand of their out puts in the construction industry. As for the clients of the construction industry, alternative and cheap finishing materials will be readily available once the project comes into force. Additionally, means of recycling plastics and alternative building materials will be achieved with the manufacturing of floor tiles from plastic and eggshell wastes.

1.7 Scope

1.7.1 Contextual scope

Contextually, the study focused on the process of making floor tiles from waste materials like plastics and egg shells, which were collected from dumping sites.

1.7.2 Geographic scope

Geographically, the study was conducted in Nairobi and in the Administrative divisions of Rubaga and Kawempe where plastic and egg shells wastes were collected.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

Daily generation and dumping of solid waste on authorized dumpsites like landfills and unauthorized site like roadsides, side drains as well as undeveloped plots of land in residential places bring about accumulation of solid waste in the environment which results into unsightly surroundings, obstruction to pedestrians and traffic flow, air pollution and groundwater pollution due to the leaching effect. Treatments as well as disposal of solid waste to free the society and environment of the menace of accumulated solid waste have been issues of serious concern to individual countries and the entire world. Various researchers have attempted to convert solid waste to beneficial applications, with a high level of success, as a way of reducing solid waste accumulation.

2.2 Solid waste reuse in concrete

Several studies have been conducted on the use of plastic waste in concrete. These include:

The works of Rebeiz showed that the resins based on recycled PET can be used to produce a good quality of precast concrete (Rebeiz, 2007). Many studies have been conducted on the use of scrap tire/rubber in mortar and concrete, and a research work has been published by Siddique a review paper (2008) on the use of recycled plastic in concrete (Siddique, Khatib & Kaur 2008). In the other study, Choi et al. (2005) investigated the effect of plastic waste (PET bottles) as aggregate on properties of concrete. The results obtained in this study showed that these wastes could reduce the weight by 2–6% of normal weight concrete and the compressive strength was reduced up to 33% compared to that of normal concrete. Sikalidis et al. (2002) investigated the utilization of municipal solid wastes (MSW) for the production of mortar. Batayneh et al. (2007) have shown, in their work that the decrease of compressive strength was in function of increase in the content plastic content. For a 20% substitution of sand by the waste, the compressive strength was reduced up to 70% compared to that of normal concrete. Also, researchers (Remadnia et al., 2009, Yazoghli-marzouk et al. 2007) have also studied the use of consumed plastic bottle waste as sand-substitution aggregate within composite materials for building applications. These authors showed that the density and compressive strength were decreased when the PET aggregates exceeded 50% by volume of sand. Also, It was found that the addition of plastic waste (fractions < 10%) in volume inside of cementitious matrix does not imply a significant variation of the concrete mechanical features.

Ghaly and Gill, (2004) did a study on compression and deformation performance of concrete containing postconsumer plastics. It was observed that specimens containing plastics failed at lower compressive loads as compared with those made of conventional concrete. The decrease in strength may be attributed to the weak bond between plastics and cement or the weak strength of the plastic. The effect of reducing the compressive strength of concrete by the plastic aggregates is due to the fact that plastic particles aggregates do not have the compression qualities of the conventional coarse aggregates. Despite the lower compressive loads, these specimens underwent considerable deformation and did not experience brittle failure. At failure, most of the specimens were reduced to two pyramids in the vertical direction with the top one being upside down.

Al-Jabir et.al (2009) investigated the properties of hollow sandcrete blocks made with cement kiln dust (CKD) as an additive and as a replacement for ordinary Portland cement. They observed that when CKD was used as a replacement for cement, the compressive strength and density of blocks generally decreased with higher replacement levels of cement by CKD. However, when CKD was used as an additive, within the investigated levels, an improvement in the compressive strength of up to 54% was observed.

ASTM C 270 focuses on the importance of lime and cement in defining the quality of mortar in relation to water retention, air content, and compressive strength. These parameters by themselves define the properties of good mortar using in masonry work, making of concrete and interlocking tiles. Brown and Robinson (1986) wrote “The most rigorous mortar requirements are to provide adequate and uniform bond strength and to prevent wall leakage.” Other parameters, such as workability of the mortar and durability are also important. Two types of properties should be considered. Plastic mortar properties pertain to the mortar from the time of mixing until it chemically hardens in the wall. Hardened mortar properties develop as the mortar cures after the initial chemical set. Both types of properties are important in determining the quality of the masonry application.

For glazed tiles intended for flooring, European standard EN 14411 makes it compulsory to state the abrasion resistance class of the glazed surface as a whole (glazes and decorations), after performance of the standard test according to ISO 10545-7 (1999).

According to Cheng and Wei-Ting, 2014, the combination of silica fume and polyolefin fiber in cement-based composites improved the strength properties and abrasion resistance than only use of polyolefin fiber due to the pozzolanic and filler effect. Cengiz et al., 2009, found that replacement of fly ash with cement reduced abrasion resistance of concrete and inclusion of the steel fiber improved the abrasion resistance of concrete. However, Using polypropylene fiber did not improve abrasion resistance of concrete made with or without fly ash.

2.3 Building finishing materials

2.3.1 Lime mortar as a component in lime and cement finishing material

Lime mortar mixes, whether for building, re-pointing, rendering or plastering, are essentially made from the same material. Building lime is produced by burning a naturally occurring form of calcium carbonate (such as limestone, chalk or sea shells) to form quicklime by driving off carbon dioxide. The quicklime is mixed with water (this can produce a vigorous reaction which generates heat) to form lime putty in a process poorly executed repairs in Portland cement known as slaking. Lime putty is most commonly used for internal plastering, and the dry powder (more commonly known as builders lime) is used as an additive to cement mortars to improve workability.

Hydraulic lime is produced from a limestone which contains clay-based minerals. Hydraulic lime is available as a dry powder. It is commonly used for external work as it can withstand more aggressive conditions.

2.3.2 Cement mortar as a finishing material

Ordinary Portland cement is made by heating limestone with clay or sand in a kiln in a controlled manner to produce “clinker”. Varying amounts of the mineral gypsum are added to this to give the desired setting properties. The material is supplied in bag form. The addition of water causes a reaction and the cement to set. The combination of cement, aggregate and water in different proportions forms concrete, cement plaster and cement mortar. Putting additives into cement can increase the workability of the mix, for example to allow its use as a render for external surfaces. Like lime mortars, pozzolans can also be added to affect the setting characteristics. Color additives can also be incorporated.

2.3.3 Ceramics as a finishing material

These are materials which are heated to high temperatures so as to obtain the engineering properties suitable for construction purposes. Ceramics can be organized into types or more categories in terms of composition (oxide, carbide and so on). The characteristics of some of the more common are given below. Alumina (aluminum oxide, Al_2O_3) is by far the most commonly used engineering ceramic. Alumina has a high hardness, is electrically insulating and can be produced in a wide variety of shapes and purities (typically from 80 to 99% where the remainder is composed of a mixture of inter granular glasses). Found predominantly as a substrate in the electronics industry, alumina can be used up to 1500°C in a wide range of applications.

The core material mostly used to produce interlocking tiles is granite particles, otherwise known as stone dust (pulverized granite). The word granite comes from the Latin granum, which means a grain, in reference to the coarse-grained structure of such a crystalline rock. Granite is a common and widely occurring type of intrusive, felsic, igneous rock (Ohijeagbon et al., 2012. The aggregated materials of interlocking tiles are usually bound together with cement. Cement is basically a binder which sets and hardens independently, and can bind other materials together when hydrated. In India, Fiori and Brusa, (1983), fabricated ceramic tiles the water absorption of which varied between with 0.1% to 2.5%. Their tiles were made using blast furnace slag. Investigation by Ramesh et al., (2013) found that using steel fiber content of 1.5% and cement up to 30% by fly ash in concrete enhanced impact resistance. Steel fibers varied from 0%, 0.5%, 1% and 1.5% by weight of cement and replacement of fly ash varied from 0%, 10%, 20%, 30% and 40% by weight of cement.

2.3.4 Terrazzo floor finishing material

Terrazzo is a highly versatile solid surface material invented by Venetian mosaic workers in the15th century. Traditionally, terrazzo is comprised of marble chips embedded into a cement base, then ground flat and coated with a topical sealer (see Plate 2.1). Although modern terrazzo can be made from a wider range of materials and polished without coatings, the craft of installing it pretty much remains the same.

Today’s terrazzo is made with either Portland cement or epoxy as its base, then combined with some type of aggregate to provide it's unique speckled look. Although marble is still the aggregate of choice for most applications, terrazzo can also be made from recycled glass and metals, as well as natural aggregates such as mother of pearl. Terrazzo can also be set into precision cut forms to create logos, medallions, text, or any abstract pattern imaginable.

Advancements in technology have provided methods for finishing terrazzo without the use of coatings and sealers. Modern terrazzo is mechanically polished to a high-shine without using any chemicals. For this reason, terrazzo is also environmentally friendly and requires very little maintenance.

Terrazzo has been rediscovered by contemporary architects and designers because of its timeless beauty and versatility. Not only does terrazzo make an impressionable floor, but can also be used in the fabrication of counters, bars, table-tops and vanities. Terrazzo is a craft that can be molded and created into anything imaginable.

a) Materials for making a terrazzo floor finishing material

Terrazzo is composed of two major materials: stone chips or aggregates of other materials, and a binding material. The latter usually consists of finished concrete or a synthetic such as epoxy resin. When resins are used, the finished product is known as thin-set terrazzo. The more expensive types of terrazzo are normally composed of finished concrete with fine marble chips or other stone. Most anything can be placed in either, though, including glass, porcelain and metal.

Plate 2.1: Terrazzo tile

b) Marble chips

Marble has been defined as a metamorphic rock formed by the recrystallization of limestone. However, in recent decades, marble has been redefined to include all calcareous rocks capable of taking a polish (such as onyx, travertine, and attractive serpentine rocks). Marble is quarried, selected to avoid off color or contaminated material, crushed and sized to yield marble chips for terrazzo. Excellent domestic and imported marble chips are available for use in terrazzo in a wide range of colors and can be combined in infinite varieties to create color harmonies of every description.

2.4 Properties of finishing materials

These properties include mechanical which describe a material's ability to compress, stretch and bend physical and chemical properties. They affect how the material functions and the durability of the material. They are given as below;

2.4.1 Mechanical properties of building finishing materials

a) **Strength:** The general ability of a material to withstand an applied force for example tensile and compressive strength

b) **Hardness:** Hardness is a measure of how easily a material can be scratched or indented. Hard materials are often also very brittle - this means they have a low resistance to impact. Well known hard materials include diamond and hardened high carbon steels.

c) **Brittleness:** A material that has a tendency to break easily or suddenly without any extension first. Good examples are Cast iron, concrete, high carbon steels, ceramics, and some polymers such as urea formaldehyde (UF).

d) **Toughness:** A material that absorbs impact (sudden forces or shocks such as hammer blows) well is tough - this is the opposite of brittleness. [Units for toughness are Joules/m^2].

e) **Plasticity:** The materials which deform permanently when small forces are applied show plasticity. Plastics and clay are good examples.

f) **Elasticity:** The ability of a material to return to its original form after a load has been applied and removed. Good examples include rubber, mild steel and some plastics such as nylon.

g) **Stiffness:** This means the ability of a material to resist bending.

h) **Compressive strength:** This is defined as the ability of a material to withstand pushing or squeezing forces (compression).

i) **Tensile strength:** This is the ability of a material to withstand pulling or stretching forces (tension). Tensile strength is given in MN/m^2.

j) **Durability:** This is the ability of a material to withstand wear and tear through weathering and corrosive attack.

k) **Stability:** This is a general property of resistance to changes in shape or size.

2.4.2 Physical properties of building finishing materials

a) **Conductivity:** This is how well a material conducts heat. Majority of the metals are good conductors of heat, more so copper and aluminum. Thermal conductivity is given in W/mK. Copper, a good conductor has a value of 283 while lead has 35 and rubber (insulator) has a value of 0.15.

b) **Electrical conductivity:** This means how well the material conducts electricity. Metals and graphite are good conductors. Insulators are materials that do not conduct electricity - plastics (polymers), rubber (elastomers) and ceramics are all insulators.

c) **Magnetic:** Some metals can be magnetized (most steels). Ferrous metals are generally magnetic, that is, able to be attracted by a magnet. There are some ceramic materials that have magnetic properties.

d) **Corrosion resistance:** This is the ability of a material to withstand environmental attack and decay. Plastics are developed or modified to withstand hostile environments For example; uPVC is resistant to the effects of UV light which would quickly cause normal PVC to become brittle. A range of coatings and surface finishes are used to improve materials appearance and corrosion resistance.

2.5 Properties of ceramic tile

Ceramic tiles possess a wide range of properties, and certain tiles are better suited for some installations than others. Few tiles are suited for all types of installations; consequently, precise knowledge of the properties is essential for the consumer to achieve the desired and anticipated value of the tile (Michael, 2008). These include:

a) Water absorption

The ability of a tile's bisque to absorb water or moisture. ASTM test method C373 measures the rate of absorption as a percent of the volume of the body of the tile, with different designations for dust-pressed, extruded, and other body forms.

Water absorption capacity identifies the nature of the ceramic body in regard to internal structure, which is related to mechanical strength (measured by modulus of rupture and breaking strength) and also other characteristics that affect ceramic tile durability (particularly in unglazed tiles), such as resistance to deep abrasion, stain resistance, and resistance to frost/thaw cycles, as well as to dimensional quality (Sveda, 2003).

b) Visual abrasion resistance

A measure of the resistance of tile surfaces to visible surface abrasion. The ASTM C1027 test applies to glazed floor, quarry, mosaic, or porcelain tiles only.

c) Aesthetic class

This is a classification that has long been needed by the tile industry especially tile show rooms to help educate tile consumers regarding color, blending, and shade variations. On one hand (the most uniform), determination of class involves precise testing (ASTM C609); but at the other extreme, the designation “Substantial Variation” requires no testing, but rather a subjective call by the manufacturer. Consequently, manufacturers and showrooms now have a positive standard and a simple classification for both commodity and artisan tiles.

Chemical resistance

The chemicals comprising this class include the most popular cleaning solutions and materials used for residential and light commercial tile installations.

d) Stain resistance

ASTM C1378 measures a tile’s resistance to the most common household stains.

e) Deep abrasion resistance

ASTM C1243 measures the resistance to wear of an unglazed tile intended for floor covering. Values depend upon the type of tile tested.

f) Freeze/thaw resistance

ASTM C1026 measures a tile’s resistance to damage induced by cycles of freezing and thawing, and rates 10 samples according to damage done at 5, 10, and 15 testing cycles.

g) Coefficient of friction

ASTM C1028 is a test to determine the coefficient of friction for manufactured tiles or for installed tiles under both wet and dry conditions. A minimum ASTM C1028 test value may be required as part of an engineer's or architect's project specification for floor tile. A value of 0.5 is considered acceptable for most applications.

h) Bond Strength

A measure of the ability of a tile to be bonded with Portland cement paste, with test values (ASTM C482) expressed in inch/pounds. The minimum value for this test is 50 psi. An especially important value for glass tiles, especially those with a smooth or coated back.

i) Breaking strength

A measure of the breaking strength of tile with test values (ASTM C648) expressed in pounds-force. Minimum value for glazed or unglazed mosaic, quarry, or paver tile is 250-pounds. Minimum value for glazed wall tile is 90-pounds. Samples of non-ceramic tiles, made of stone, glass, metal, concrete, or other materials can be submitted for ASTM C648 testing and evaluation.

j) Crazing resistance

A one cycle pass-or-fail test (ASTM C424) to determine resistance to crazing. The test uses staining dyes and steam to induce and identify thermal shock damage. Any tile claiming craze or crackle resistance should be able to pass the ASTM C424. There is no test value: The sample either passes or fails.

k) Thermal shock resistance

ASTM C484 measures glazed ceramic tiles resistance to thermal shock created by rapid or severe temperature changes, as might be found near a fireplace or stove surround, for example. The test uses staining dyes and approximate 300°F temperatures to induce and identify cracks or other damage. There is no test value: The sample either passes or fails.

l) Moisture expansion

A negative property, rarely found in ceramic tile, where prolonged moisture absorption causes a tile to permanently grow in volume. ASTM C370 is the test used to reveal this property. It is included here only to highlight that the moisture expansion phenomenon exists.

m) Facial dimensions

A measure of the uniformity of size of a particular tile, determined by ASTM test C499 with values found, under “Nominal Size”, “Caliber Range”, and “Thickness”, in ANSI A137.

n) Warpage

The curving of a flat tile surface, as measured by ASTM C485, with values found, under “Warpage Edge”, “Warpage Diagonal”, in ANSI A137.

o) Wedging

A change in edge dimension, from one tile to another, in a given lot, as measured by ASTM C502, with values found, under “Wedging”, in ANSI A137.

p) Thermal Expansion

Linear thermal expansion is determined by ASTM test C372.

q) Thickness

The uniformity of thickness for a given lot of tile is determined by ASTM C499, with values found, under “Thickness” in ANSI A137.

2.6 Use of plastics in the construction industry

According to Kiran Kumar and Prakash (2006) a material that contains one or more organic polymers of large molecular weight, solid in its finished state and at some state while manufacturing or processing into finished articles, can be shaped by its flow, is termed as plastics. Prabir Das (2004) suggested that plastics could be used in construction industry at various places. Proper selection of material / grade and suitable design considerations can help to replace many more applications. Lighter weight, design flexibility, part integration, low system cost, very high productivity and improved product appearance are the main features for use of engineering plastics. Lakshmi and Nagan (2011) suggested the use of E- Plastic particles along with fly ash to improve the properties of concrete. Vasudevan (2004), in his report gave the most useful ways of disposing waste plastics and laying roads in a research carried out by the Chemistry Department of Thiyagarajar College of Engineering. They reported that the waste plastics may be used in block making, modified light roofing, mastic flooring and polymer reinforced concrete. The blocks could take 350 tonnes of load and prevent water penetration.

There are three types of plastics namely; Thermosets, elastomers, thermoplastics. Construction represents the second largest market for plastics, consuming some 25% of all plastics consumed in the UK. The earliest commercially available plastics material was first developed in the UK and exhibited in 1862. Plastics have been used in construction applications since the 1930's. Plastics are a family of some twenty different materials each with a different range of properties. Examples of plastics used in building are: acrylic, composites, expanded polystyrene, polycarbonate, polyethylene, polypropylene, and polyvinyl chloride (Brouwer, 1992).

2.6.1 Generation and sources of plastic waste

a) Household: carry bags, bottles, containers and trash bags.
b) Health and Medicare: disposable syringes, glucose bottles, blood, intravenous tubes, catheters and surgical gloves
c) Hotel and catering: packaging items, mineral water bottles, plastic plates, and glass

2.6.2 Fundamental benefits of plastics in construction

Polymers have a number of vital properties, which when exploited alone or together, make a significant and expanding contribution to constructional needs (Brouwer, 1992),

a) Hygiene and clean
b) Plastics are easy to install: Lightweight, Snap fit
c) Plastics promote energy efficiency in building: Plastics are low conductors of heat, Tight seals achievable
d) Plastics are lightweight: Easy to transport, manoeuvre and handle, fewer accidents
e) Plastics offer design freedom: A limitless array of shapes possible, products can be colored, opaque or transparent, rigid or flexible
f) Plastics are strong: Durable, knock and scratch resistant with excellent weather ability, do not rot or corrode.
g) Plastics are cost-effective: Favorable whole-life costs, offer a combination of durability, quality, low maintenance and labour saving.
h) Plastics have a variety of waste management options available: Plastics building products can be recycled with low energy inputs and when this is not feasible can be used in energy from waste schemes.
i) Plastics score highly in environmental assessments: Plastics materials are an efficient use of resources, rated highly in BRE's 'Green Guide to Specification'

j) Plastics are low maintenance: Plastics building products can be repaired, they do not need painting.

Using Plastics in construction has a number of advantages including but not limited to:

a) It easily binds to coarse aggregates at medium temperature
b) It does not require any change in road laying practice
c) The material is available locally in the form of shredded plastic, which is presently treated as a waste
d) The process makes use of plastic bags in shredded form. The disposal of used plastics, which is an environmental problem, is thereby eliminated

2.6.3 Polyethylene Grades

a) Low density polyethylene

Low density polyethylene is an extruded material that offers good corrosion resistance and low moisture permeability. It can be used where corrosion resistance is important and not stiffness, high temperatures, and structural strength. LDPE, a highly flexible product, is used widely in orthopedics products or where mobility without stress fatigue is desired as well as in consumer packaging, bags, bottles, and liners.

b) High density polyethylene

HDPE Represents the largest portion of the polyethylene applications and offers excellent impact resistance, light weight, low moisture absorption, and high tensile strength. It is also non-toxic and non-staining and meets FDA and USDA certification for food processing.

c) Ultrahigh molecular weight polyethylene

This category has light weight (1/8 the weight of mild steel), high in tensile strength, and is as simple to machine as wood. UHMW PE is the ideal material for many wear parts in machinery and equipment as well as a superb lining in material handling systems and storage containers. It is self-lubricating, shatter resistant, long-wearing, abrasion and corrosion resistant.

UHMW PE meets FDA and USDA acceptance for food and pharmaceutical equipment and is a good performer in applications up to 180 °F (82 °C). Melting Point 115^{o}C to 135^{o}C

2.7 Use of egg shell waste material in construction

Agricultural waste constitutes a significant proportion of the accumulated solid waste in many parts of the world. Egg shells are part of agricultural wastes that litter the environment. In the ever increasing endeavors to convert waste to wealth, the efficacy of converting Egg shells to beneficial use becomes an idea worth investigating. The composition of the Egg shells lends the effects of its ash on the cement to be articulated. It is scientifically known that the Egg shell is mainly composed of compounds of calcium. Winton (2003), presented egg shell as being composed off 93.7% calcium carbonate, 4.20% organic matter, 1.30% magnesium carbonate, and 0.8% calcium phosphate.

2.8 Use of white cement as a binder to make building tiles

Physical and chemical properties of white cement

a) Appearance: A fine powder ranging in color from off-white to white

b) Odour: No distinctive odour

c) Boiling/melting Point: Melting point >1200ºC

d) Vapor pressure: Not applicable

e) Specific gravity: 3.0 – 3.2

f) Flash point: Not applicable

g) Flammability limits: Not applicable

h) Solubility in water: Slight, reacts on mixing with water forming an alkaline (caustic) solution (pH >11)

i) Particle size: Up to 50% of the fresh dry material may be respirable (below 10 microns)

Contact with cement mixed with water or body fluids (for example sweat or eye fluid) or with concrete or mortar should be avoided as it may cause irritation, dermatitis or burns. If such contact occurs, the affected area should be washed without delay with plenty of clean water. In case of eye contact rinse immediately with clean water and seek medical advice.

2.9 Research gap

This research was carried out with the concern of reducing wastes in the environment by using them to make construction building floor tiles. This study looked at floor building tiles with these waste materials and the compressive strength, density, water absorption, abrasion and impact resistance tests were conducted on the tiles to investigate their suitability for use in the construction industry.

CHAPTER 3: MATERIALS AND METHODS

3.1 Determination of the optimum proportions of the waste materials for maximum strength of building tiles

This involved collecting the wastes, cleaning, drying, crushing and grinding them, determining the density of the ingredients and determining the volumes of the respective moulds that were used in the study.

3.1.1 Collection and processing of solid waste materials

a. Collection and processing of plastics

Plastics were collected especially from hospitals and other dumping sites, were washed and shredded into pieces of 1 mm average diameter (see Plate 3.1).

Plastic is a strong material and it is resistant to both chemical and physical attacks making it hard to disintegrate. It is also resistant to the penetration of water which is why it is considered one of the major threats to the fertility of our soils. This has made it a suitable component in this material since it increases on the water penetration resistance of the material. Plastics also increase the bonding in the composite material. Plastics were mainly used as fill materials to increase the bulk and reduce on the use of other materials like cement and egg shells.

Plate 3.1: Sorted and crushed plastics

b. Collection and processing of egg shells

The egg shells were obtained from poultry farmers, hotels, JKUAT cafeteria; they were subjected to thorough cleaning involving soaking in water for 24 hours allowing easy removal of dirt and membranes during cleaning. The major component of egg shells being calcium carbonate makes them a very important material. The egg shells are resistant to water penetration making its combination with plastics suitable for their use.

(a) Eggshells before being processed

(b) Tiles and eggshells

(c) Crushed eggshells (d) Pounded eggshells

Plate 3.2: Egg shells during drying and after being processed

Egg shells were first put in boiling water for 5-10 minutes to remove the membrane and then sun dried for 3-4 days and then some were pounded using a motor and pestle(see plate 3.3) and others crushed using a milling machine (Plate 3.4). The pounded egg shells were sieved through a 1.2mm sieve (Plate 3.5). The egg shells were used to increase the bulk and reduce on the use of other materials.

Tools and equipment used

Plate 3.3: Motor and pestle for pounding the egg shells

Plate 3.4: Milling machine in BEED used to crush the egg shell to powder

Plate 3.5: Researcher sieving the pounded egg shells

c. White cement as a binder

This is a third component that binds the plastics and egg shells to make a material which is resistant to water penetration. In this case, white cement was used to bring out the colors of plastics and egg shell respectively. White hydraulic cement is good ingredient because it is resistant to water infiltration and will increase the strength of the material. White cement (Plate 3.6) was basically used for aesthetics properties. However, the common ordinary Portland cement (OPC) can be used. Clean drinking water was used for mixing the ingredients.

Plate 3.6: White cement

3.1.2 Mixing the materials after proportioning

i. **Mixing plastics, Egg shells and cement and casting cubes**

The densities of plastics, white cement and egg shells were 400 kg/m^3, 1,440kg/m^3, and 1,290kg/m^3, respectively**.** For the production of building tiles, crushed plastics, crushed and pounded egg shells and white cement were mixed in different quantities (Table 3.1). Commercial production of these tiles should aim at minimizing the cost of production.

In order to manufacture the tiles, a ratio that gave the maximum compressive strength was used. Nine (9) cubes were cast for each ratio; they were cured for 28 days under water. Three cubes for each ratio were tested for compressive strength at 7, 14 and 28 days respectively.

Table 3.1: Quantities (kg) of different materials in each ratio

Cement: plastics: egg shells	Cement (kg)	Plastics (kg)	Eggshells (kg)
(1:1:0)	0.94	0.26	0.00
(1:1:1)	0.62	0.17	0.56
(1:1:2)	0.47	0.13	0.84
(2:1:1)	0.94	0.13	0.42
(1:2:1)	0.47	0.26	0.42
(1:2:2)	0.37	0.21	0.67
(2:1:2)	0.75	0.10	0.67
(2:2:1)	0.75	0.19	0.30
(1:0:1)	0.84	0.00	0.84
(2:0:1)	1.25	0.00	0.56

The porker vibrator, trough, spades, a trowel, steel float were some of the tools that (see Plate 3.7) were used in casting the cubes.


(a) Porker vibrator (b) Trowel


c) Trough d) Spades

Plate 3.7: Tools and equipment

The ingredients from table 3.1 (cement, plastics, crushed and pounded egg shells and water) were weighed using the measuring scale and then mixed in a trough (Plate 3.8) and then cast in already prepared moulds (Plate 3.9) and vibrated using a vibrator and then left in the mould for 24 hours after which they are demoulded and cured (see Plate 3.10) for 28 days. The cubes were subjected to testing in a compressive strength testing machine (Plate 3.11) and the results were obtained and recorded (Figure 4.4).

Plate 3.8: Ingredients in the trough before and after mixing

Plate 3.9: Cast cubes

Plate 3.10: Cubes curing

Plate 3.11: Universal testing machine

ii. Making of the tiles

After obtaining the ratio (2:1:1) that gave the maximum strength, the making of the tiles commenced. Moulds of different sizes (300x300x10mm, 200x200x10mm and 180x180x10mm), were used to make these tiles (Table 3.12). The mixture of white cement, plastics and crushed Egg shells was hand compacted into the moulds and the surface finished smooth using a steel float and then the tiles are left to set and dry in the moulds for 24-48 hours before they were removed and let to dry at room temperature. The mixture was made fairly plastic to enable proper compaction manually. Three moulds of 200x200x10mm, one mould of 300x300x10mm and one mould of 180x180x10mm were used in the study.

Plate 3.12: Moulds used to make tiles

Plate 3.13: Making the tiles with the moulds

Plate 3.14: Appearance of tiles Plate

3.2 Testing tiles for physical and mechanical properties

3.2.1 Physical properties of tiles

a) Water absorption rate *ASTM test method C37, EN99*

The capacity of a ceramic material to absorb water is related to its porosity. Fully-vitrified stoneware, a compact material with low porosity, has water absorption values below 0.5%.

The strength of any building material will be drastically reduced if allowed to absorb excessive moisture. This is the major reason for restricting the application of the material without a protective measure such as DPC and DPM covering which are more resistant materials to weather.

The water absorption value will have a direct bearing on other performance characteristics such as mechanical resistance, the resistance to sudden temperature changes and frost resistance. It also gives us an idea of the degree of internal cohesion and compaction of the fired product. The open porosity of a wall or floor tile firstly depends on the composition of the ceramic body. This may vary considerably from one product to another (porcelain floor tiles have low porosity; wall tiles are very porous). Other determining factors include the compaction of an unfired piece or piece-forming (which in turn depends on such other factors as grain size, distribution of the spray-dried powder, moisture etc.) and, finally, the firing process. Water absorption is also used as a criterion for classifying ceramic wall and floor tiles in ISO 13006: 1998. Obviously, the glazed layer has zero water absorption since it is fully vitrified.

The procedure involved the following:

a. Cubes from each mix ratio were randomly selected.
b. The cubes were dried in an oven for 24 hours at 60^{o}Cto ensure that all the water was removed.
c. The dried cubes were weighed and recorded as M_1.
d. Then the cubes were immersed in water for 24 hours.
e. Their weights were measured accurately and noted as M_2.

Then the formula below was used to obtain the results

$$[(\mathbf{M_2} - \mathbf{M_1}) \cdot \mathbf{100}]/\mathbf{M_1}$$

Where: $\mathbf{M_1}$= the mass of the dry tile, $\mathbf{M_2}$= the mass of the wet tile.

The average absorption of water of the sample was determined by the arithmetic average of the individual results, and results must be rounded off to a single decimal place.

b) Density of the cubes

This is the mass of the material per unit of its volume. It is an important factor influencing all strength properties of the material. Determination of density of a regular shaped material such as a cube of mortar involved a simple procedure of weighing the sample accurately and then measuring its dimensions well to compute its volume.

$$\mathbf{Density} = \frac{\mathbf{Mass}}{\mathbf{Volume}}$$

With the above formula, the density test of the material was calculated using the simple procedure below.

a. A cube was selected at random and its mass weighed accurately.

b. Then its dimensions were accurately determined to find their volume.

$$\mathbf{Volume} = \mathbf{L \cdot B \cdot TH}$$

where**L** = length, **B** = breadth and **TH** = thickness

c. The density was calculated using the above formula.

3.2.2 Mechanical properties of building tiles

a) Impact resistance test (Porcelanosa, 2005)

Impact can be defined as the application of a high degree of instantaneous force on a minimal surface, and is generally negative for ceramic products. Heavy or pointed objects falling on tiles may damage or shatter the surface, depending on the type of object.

The determination of impact resistance is addressed in the American standard through measuring what is known as the restitution coefficient (ASTM C648-84)

A spherical steel bearing weighing approximately 438g was dropped from a height of one meter above the surface of the tile samples and the degree of shuttering or indention was recorded.

A spherical steel ball weighing approximately 438g (see Plate 4.1) was dropped on to the sample tiles at a height of one meter (see Plate 4.2) by using a steel reinforcement of 1 meter height and the degrees of damage to the sample tiles were recorded.

Plate 3.15: 438g spherical steel bearing

Plate 3.16: Spherical steel bearing dropped through one meter

Surface abrasion resistance test ASTM C1027

Porcelanosa, (2005) believes that the degree of a ceramic tiles' resistance to abrasion on its glazed surface is the factor that is going to essentially determine its durability. Therefore an in-house method has been developed to give a clearer idea of how tile samples withstand wear and loss of appearance.

The test reproduces and even exaggerates the real abrasion conditions that any floor tiles are subject to. Used as an abrasive agent is a quantity of sand with a high silica content (with a hardness of 7 on Mohs' scale), which is placed on the sample.

This abrasion of the tile surface is maintained during 10 minutes, after which the extent of the wear is assessed.

For this study, a weight of 8.4kg was used alongside abrasive sand to test for the abrasion of the tiles. The sample tiles were weighed before undergoing the abrasion test and after the test. The two weights before and after abrasion were recorded. The abrasion effect was assessed on the basis of effective percentage weight loss.

PRESENTATION OF RESULTS

Results were presented using photos and mostly Microsoft excel inform of graphs, tables and graphs.

CHAPTER 4: RESULTS, ANALYSIS AND DISCUSSIONS

4.1 The effect of cement, plastics and egg shells on compressive strength of cubes

The compressive strength of cubes increased with increased quantities of cement. The compressive strength increases with increasing amounts of cement upto approximately 60% beyond which the compressive strength starts decreasing because, cement reaches the brittle state. At a minimum compressive strength of 10 N/mm^2, about 44% of cement is required. Compared to plastics and egg shells, cement contributes most significantly to the compressive strength of cubes (Figure 4.1).

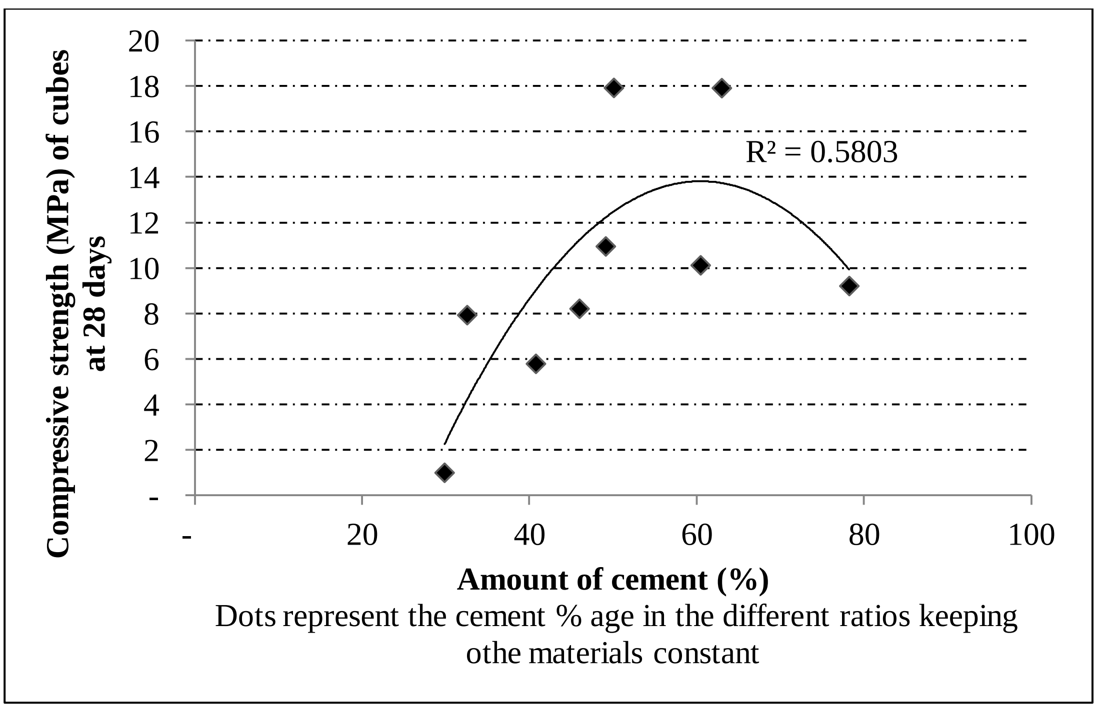

Figure 4.1: Effect of variation of cement content on the cube compressive strength

The compressive strength of the cubes was negatively affected by the addition of plastics (Figure 4.2). This is consistent with the findings of Ghaly and Gill, (2004). The decrease in strength may be attributed to the weak bond between plastics and cement or the weak strength of the plastic. The effect of reducing the compressive strength of concrete by the plastic aggregates is due to the fact that plastic particles aggregates do not have the compression qualities of the conventional coarse aggregates. At a minimum compressive strength of 10 N/mm^2, about 13% of plastics is required.

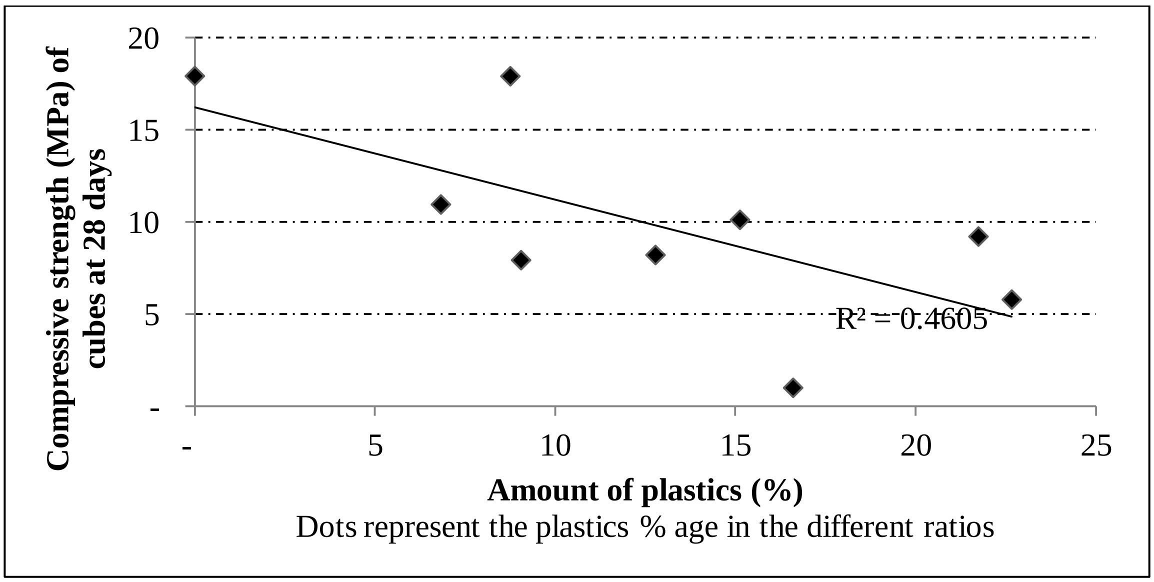

Figure 4.2: Effect of variation of plastics content on cube compressive strength

The effect of egg shells on the compressive strength of the cubes was insignificant (Figure 4.3). At a minimum compressive strength of 10 N/mm^2, about 35% of cement is required. Egg shells are a neutral filler material composed of $CaCO_3$ when pulverized (King'ori, 2011). They are used to increase the bulk of the mixture and reduce on the quantities of other mix ingredients.

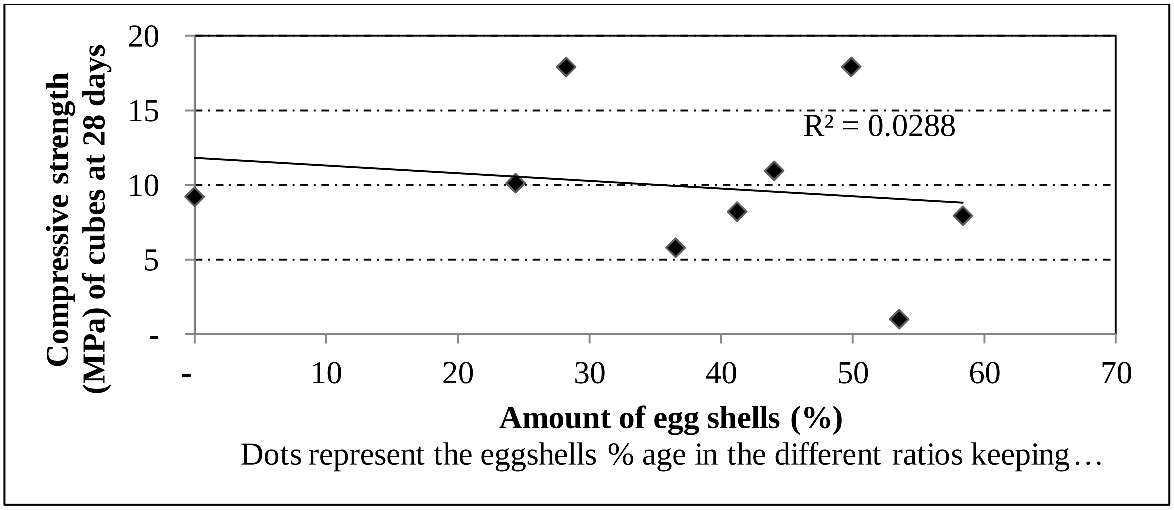

Figure 4.3: Effect of variation of egg shells content on the cube compressive strength

The highest strength (21 N/mm^2) was realized for a cement: plastic: egg shell ratio of 2:0:1 (Figure 4.4). A compressive strength of 17.9 N/mm^2 after 28 days' curing was realized for ratios of 2:1:1 and 1:0:1. Ratio of 1:2:2 with the largest quantity of plastics resulted in cubes with the lowest (about 1 N/mm^2) compressive strength (Figure 4.4). The compressive strength of the cubes made with a mixture of ratios 2:0:1 and 2:1:1 had the same strength as class 15 to class 20 concrete (Hirschi et al., 2005) (Figure 4.5). Cubes with the highest compressive strength were those with high cement content or without plastics.

Table 4.1: Shows average cube compressive strength (MPa)

Mix ratio	**Average cube compressive strength (MPa)**
(1:1:0)	9.20
(1:1:1)	8.20
(1:1:2)	7.92
(2:1:1)	17.90
(1:2:1)	5.78
(1:2:2)	0.99
(2:1:2)	10.94
(2:2:1)	10.11
(1:0:1)	17.91
(2:0:1)	21.22

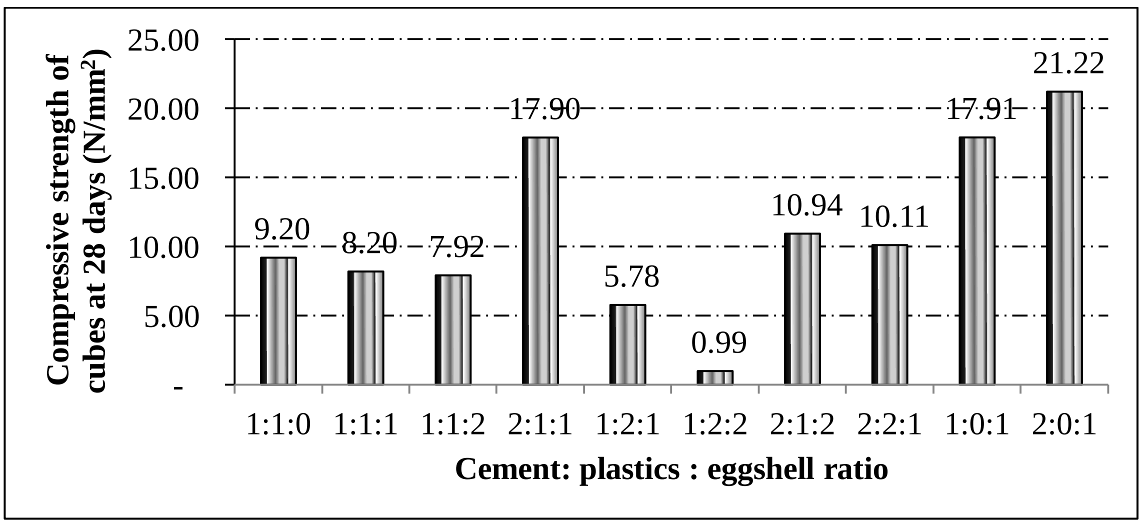

Figure 4.4: Compressive strength of cubes

In conclusion, the highest compressive strength (21.22 N/mm^2) was obtained without plastics. Since the major objective was to get rid of waste materials by making use of them in making construction floor tiles, the mix ratio containing cement, plastics and egg shells that gave a compressive strength of 17.9 N/mm^2 was considered the most appropriate. Tiles with both compressive strengths were manufactured to obtain impact and abrasion resistance results.

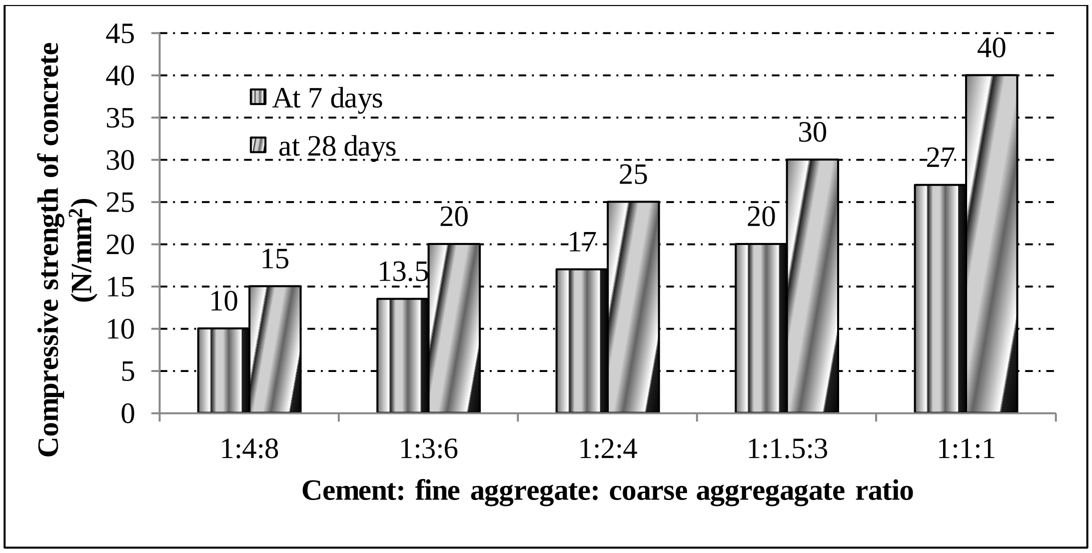

Figure 4.5: Compressive strength of various grades of concrete

4.2 Water absorption results of the cubes

Cubes with high quantities of cement had low water absorption rates while those with more plastics and egg shells had high water absorption rates (Figure 4.6). Cubes made from cement: plastics: egg shells ratio 1:2:2 had the highest water absorption rate (33.4%). This might have been due to more quantities of plastics and egg shells. Cubes made from cement: plastics: egg shell ratio of 2:1:1 had the lowest water absorption rate (11.4%).

Table 4.2: Shows the cube water absorption (%)

Mix ratio	Water absorption (%)
1:1:0	16.9
1:1:1	15.5
1:1:2	16.4
2:1:1	11.4
1:2:1	21.4
1:2:2	33.4
2:1:2	19.9
2:2:1	21.6
1:0:1	14.0
2:0:1	32.7

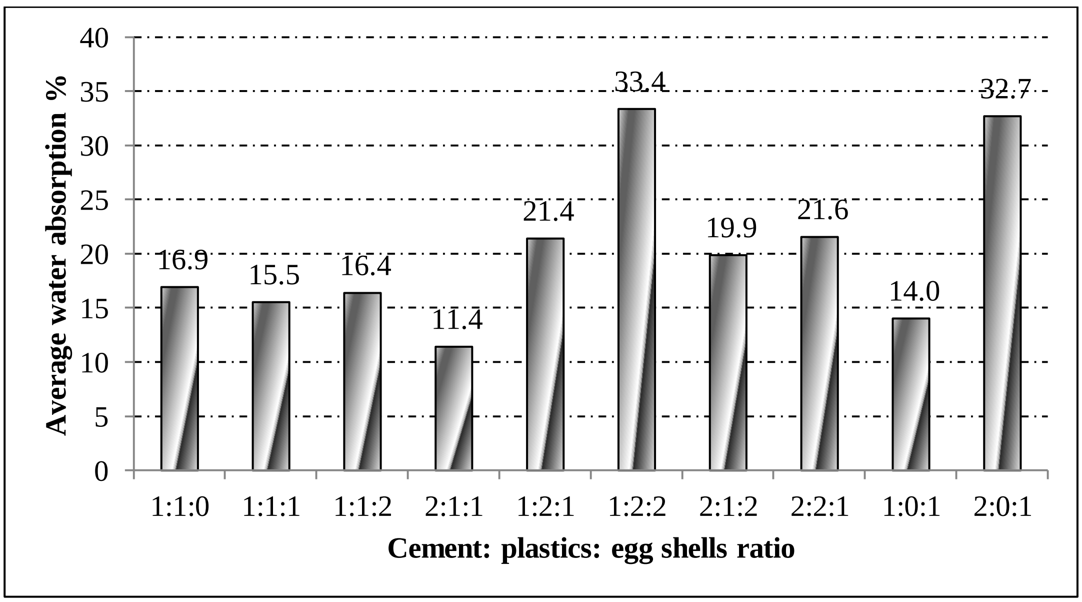

Figure 4.6: Water absorption of the cubes

According to Kenya bureau of standards, floor tiles with water absorption rate in the range of 6-10% have an allowable individual maximum of 11% water absorption. Therefore, since these tiles have 11.4% water absorption rate, they can convincingly be used as floor finish materials.

4.2.1 The effect of cement, plastics and egg shell contents on the water absorption rates of cubes

Cubes water absorption decreased with increased cement content while increased water absorption was obtained with reduced cement content. However, the relationship between the cement content (%) and water absorption was not a strong one (Figure 6). In comparison with the plastics and egg shells, it can be concluded that cement was the main contributor to reducing water absorption of the cubes (Figure 4.7).

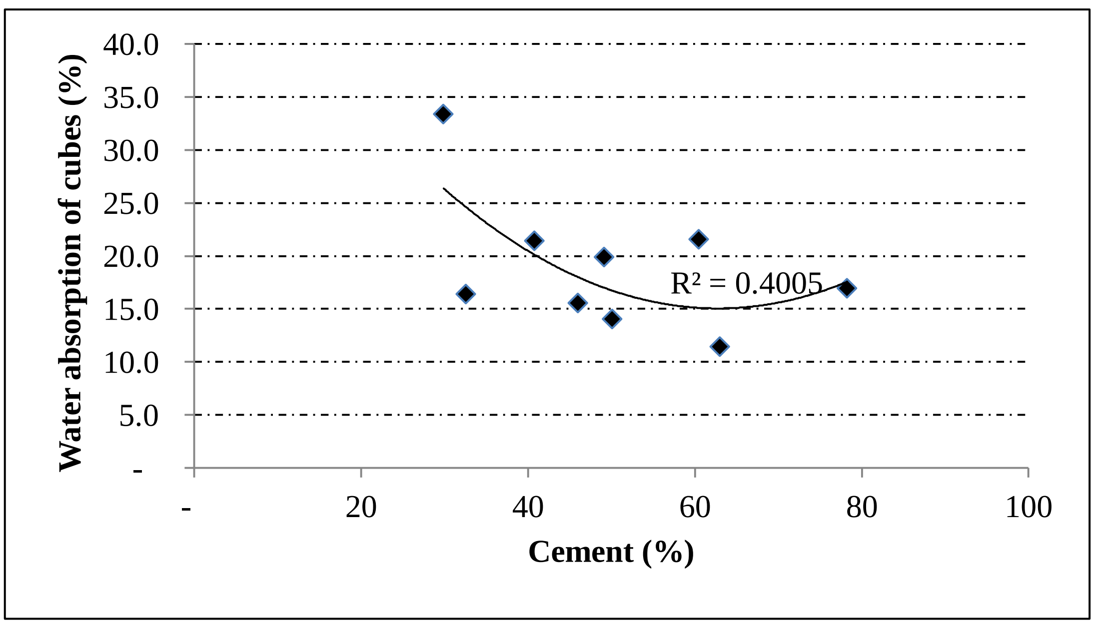

Figure 4.7: Effect of cement (%) on the water absorption of cubes

The contribution of plastics to water absorption is too minimal as shown by the weak relationship between them and the water absorption. Therefore, Plastics have a very insignificant effect on the water absorption of the cubes (Figure 4.8).

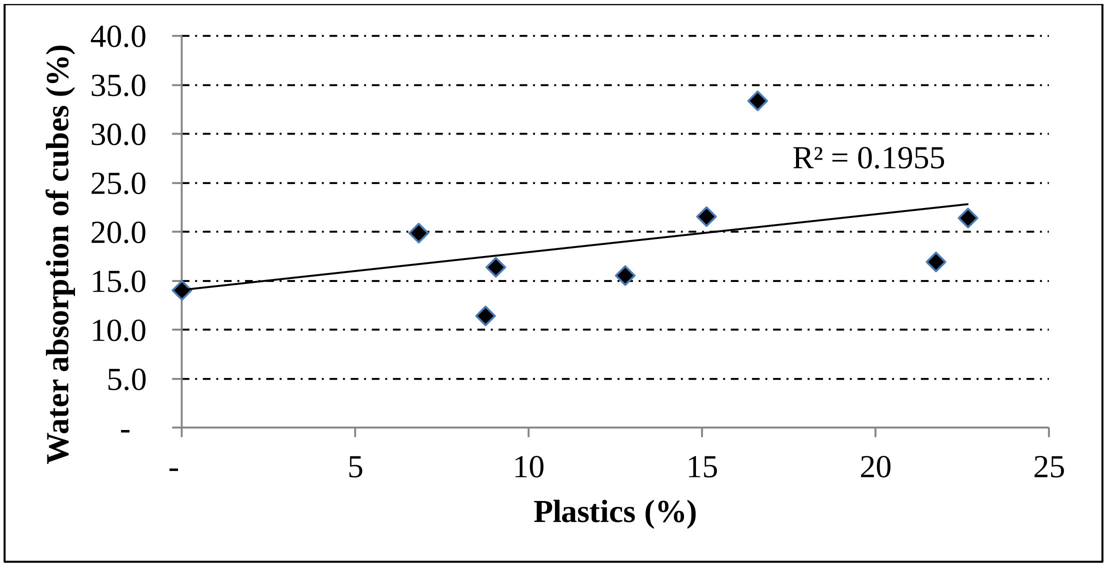

Figure 4.8: Effect of plastics (%) on the water absorption of cubes

Eggshells had a very insignificant effect on the water absorption of the cubes (Figure 4.9). This is shown by the very weak relationship between percentage egg shells and the percentage water absorption (5.7%) of the cubes.

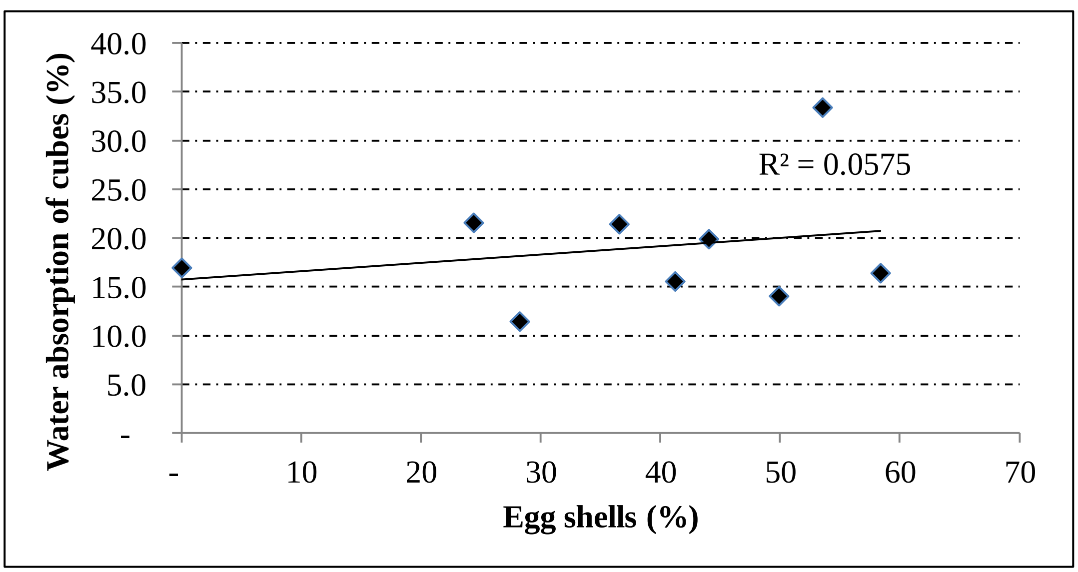

Figure 4.9: Effect of plastics (%) on the water absorption of cubes

In conclusion, water absorption was mainly influenced by the amount of cement. The contribution of plastics and egg shells to water absorption was too insignificant.

4.3 Density results of cubes

Cubes with more cement content had high density values while those with high quantities of plastics had low density values (Figure 4.10). Cubes made from cement: plastics: egg shells ratio 1:2:2 had the density (1,305 kg/m^3) while those made from cement: plastics: egg shells ratio 1:0:1 had the highest density (2,086 kg/m^3). The high density could be as a result of proper compatibility of cement and egg shells mixture.

The density results show that the densities of the different mix ratios ranged from 1,305 kg/m^3 to 2,086 kg/m^{3}which compare well with the densities of the different classes of concrete which range from 1,200 to 2,500 kg/m^3.

Table 4.3: Shows density of cubes (Kg/m^3)

Cement: plastics: eggshells ratio	**Density (kg/m^3)**
1:1:0	1,595
1:1:1	1,782
1:1:2	1,796
2:1:1	1,901
1:2:1	1,617
1:2:2	1,305
2:1:2	1,834
2:2:1	1,705
1:0:1	2,086
2:0:1	1,960

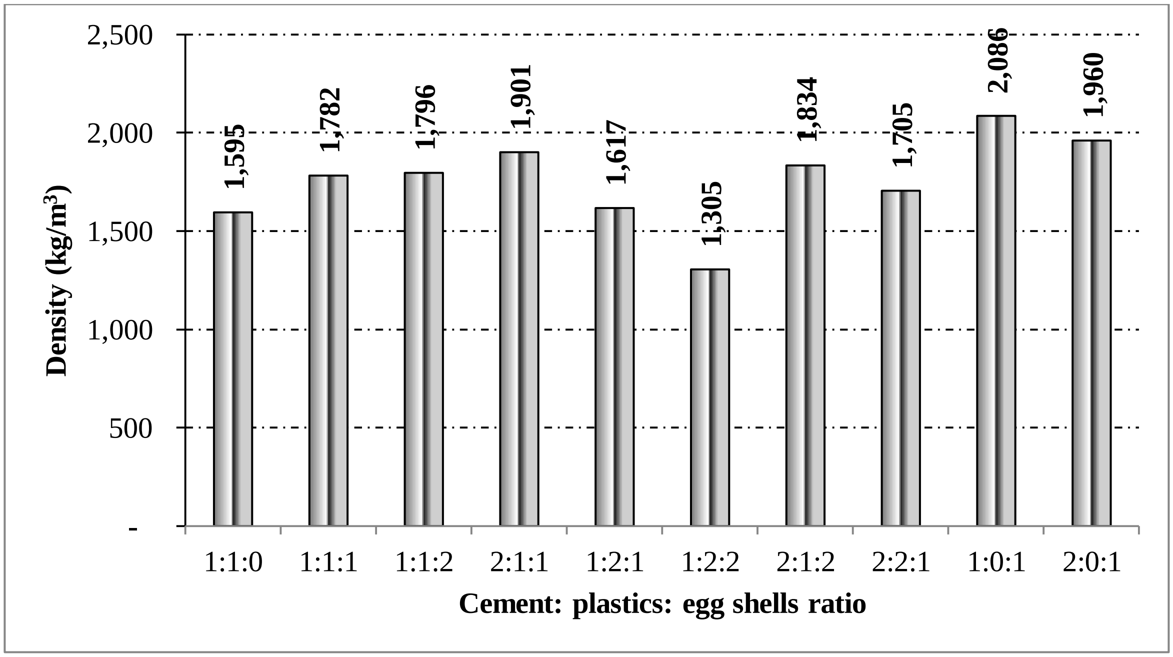

Figure 4.10: Densities of cubes made with different mix ratios

4.3.1 Effect of the ingredients on the density of cubes

The density of tiles increased with increase in the quantity of cement up to approximately 60% when density started to decrease (Figure 4.11). Cement has 58% degree of significance of contribution to density of cubes.

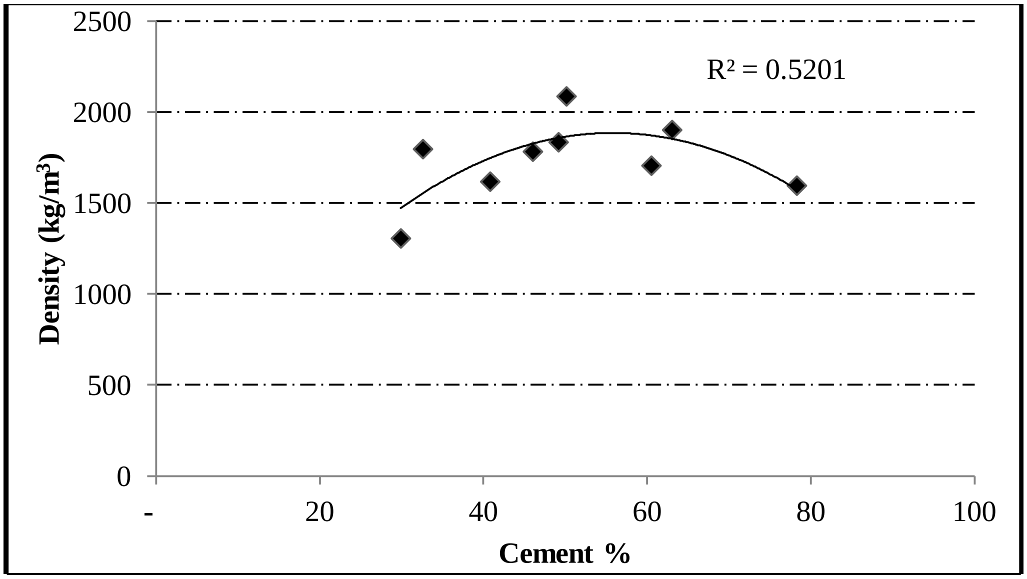

Figure 4.11: Effect of variation of cement content on the cube density

The density of cubes decreased with an increased plastic quantity. When the quantity of plastics was zero, the density of the cubes was maximum at 2,086 kg/m^3 (Figure 4.12).

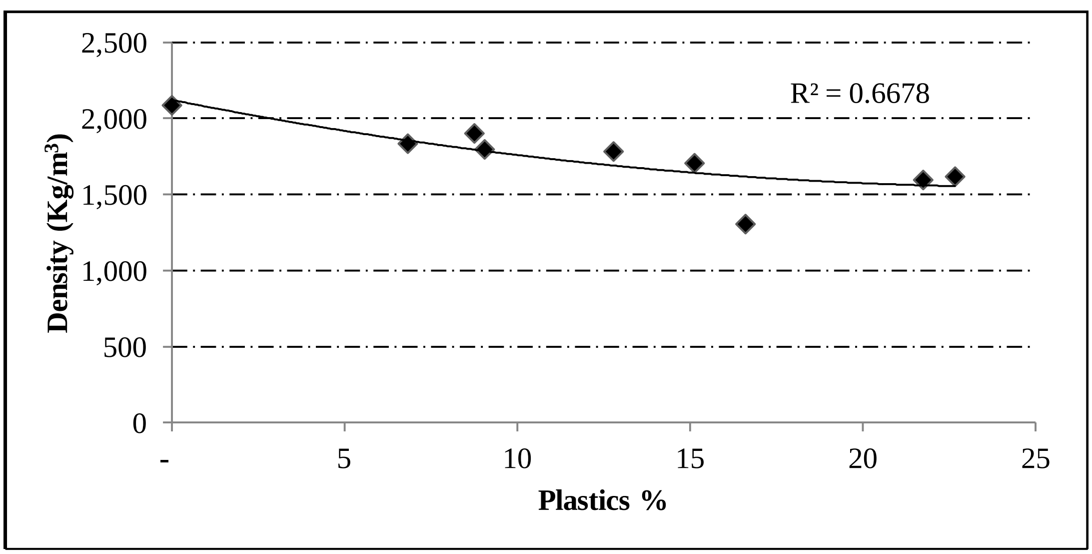

Figure 4.12: Effect of variation of plastics content on the density of cubes

The effect of egg shells on the density of the cubes was very insignificant (Figure 4.13). However, with increase in egg shell quantity, the density of the cubes slightly increased up to approximately 45% beyond which, the density started deceasing.

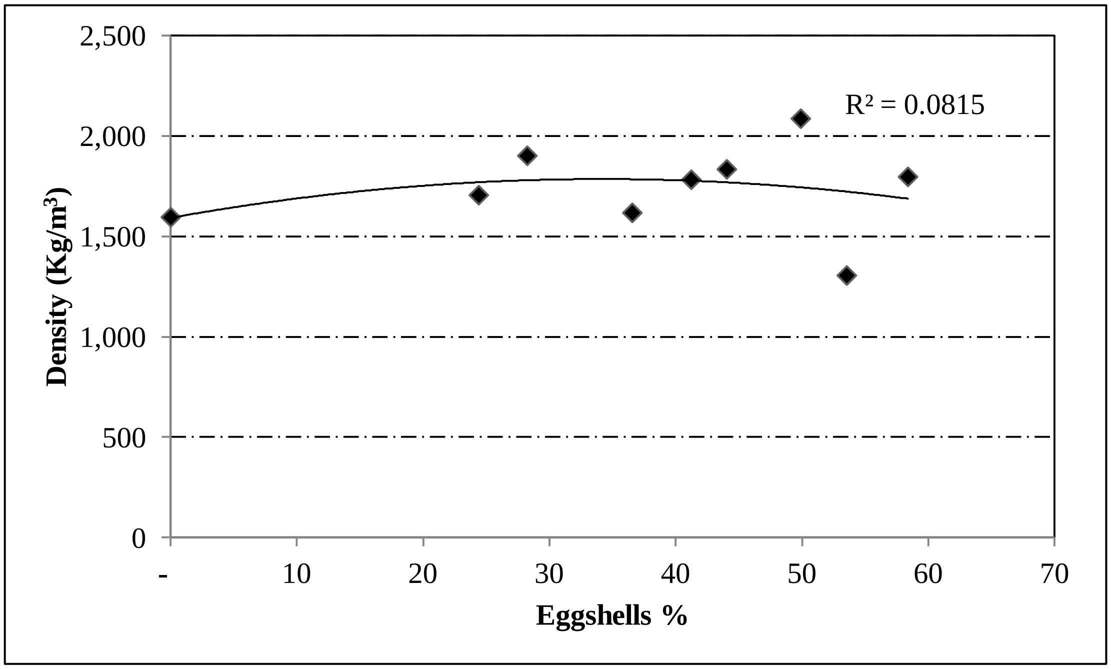

Figure 4.13: Effect of variation of egg shells on the density

4.4 Surface abrasion results

Experimental results showed that the presence of plastics in the tiles increased abrasion resistance.

4.4.1 Effect of plastics on surface abrasion

Surface abrasion results show that tiles with cement, plastics and egg shells (2:1:1) wear at a rate lower than those made with cement and egg shells only (2:0:1) (Figure 4.14). The absence of plastics makes the tiles weak and easily eroded by any rubbing object while presence of plastics makes the tiles more resistant to surface abrasion.

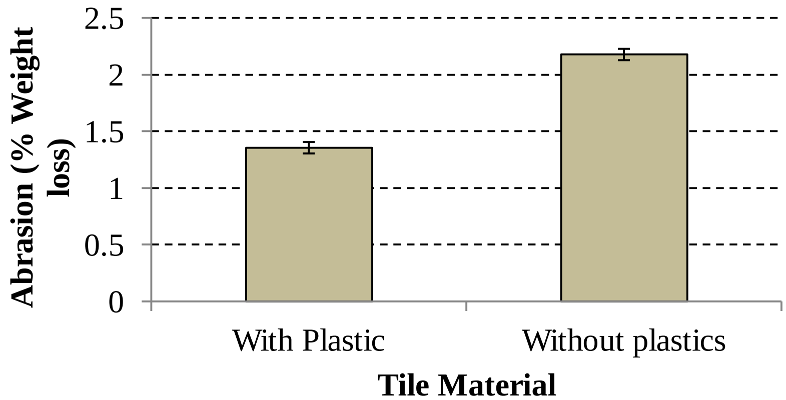

Figure 4.14: Effect of plastics on abrasion

4.5 Impact resistance test results

The spherical steel ball when dropped on the tiles made during this study only caused dents without shattering (see Plate 4.3). The inclusion of plastics in the mixes used to produce the tiles reduced the brittleness of these tiles. When the spherical steel ball was dropped onto tiles without plastics, the tiles shattered (see Plate 4.4), implying that they were brittle. When the test was conducted on the commercial ceramic industrial tiles, they shattered completely (see Plate 4.5). This implied that the industrial ceramic tiles were brittle in nature.

Plate 4.1: Indented tiles made with cement, plastics and egg shells

Plate 4.2: Shattered tile made with cement and egg shells without plastics

Plate 4.3: Shattered commercial ceramic tile

In a nut shell, the presence of plastics in the tiles under study reduced their brittleness making them suitable for use as floor tiles.

The bending strength could not be measured because of the brittleness of the tiles. The weight of the apparatus caused failure of the tiles before any bending strength results could be recorded by the universal testing machine.

In conclusion, an appropriate combination of cement, plastics and egg shells (2:1:1) provided the highest impact and abrasion resistances, from which it was inferred that plastics were important in increasing impact and abrasion resistances of the tiles.

4.6 Economic consideration of tiles

Table 4.1 shows the sizes of tiles made during this study and their relevant information. Table 4.2 shows the cost of commercially available ceramic tiles of the same size as the tiles made during this study. The cost of production of the tiles used in this study is carried out in Table 4.3

Table 4.4: Tile information

Dimensions (mm)	**Area (m^2)**	**Volume (m^3)**	**Number of tiles/m^2**
300x300x10	0.09	0.001	12

Table 4.5: Cost of commercial ceramic tiles

Tile type and size	**Coverage (m^2)**	**Cost (Kshs)**
Floor tiles 300mm x300mm	1	900-1500
Wall tiles 300mm x300mm	1	800-1500

Table 4.6: Unit cost for plastics, egg shells, cement and tiles

INGREDIENT: PLASTICS			
Activity	**Rate (Kshs/kg)**	**Qty (kg)**	**Amt (Kshs)**
Collection washing and drying	5	1	5
Crushing cost	10	1	10
Total			15
Cost (Kshs) per kg			**15**
INGREDIENT: EGG SHELLS			
Activity	**Rate (Kshs/kg)**	**Qty (kg)**	**Amt (Kshs)**
Collection Washing and Drying fee	10	1	10
Crushing cost	10	1	10

Total			20
Cost (Kshs) per kg			**20**
INGREDIENT: CEMENT			
Activity	**Rate(Kshs/kg)**	**Qty(kg)**	**Amt (Kshs)**
Buying	35	1	35
Total			35
Cost (Kshs) per kg			**35**

COST OF PRODUCTION (Kshs) OF CEMENT, PLASTICSAND EGG SHELLS MIX TILES FOR RATIO 2:1:1				
	Cement	**Plastics**	**Egg shells**	**Total**
Quantities (kg)	0.84	0.12	0.38	
Cost (Kshs)	29.4	1.8	7.6	38.8
15% for transport, other costs and profit margin				5.82
Total				44.62
		cost/tile	**tiles/m^2**	**Cost/m^2**
Cost/m^2 (Kshs)		44.62	12	**535**

From the economic analysis, it can be concluded that the cost of the tiles made in this study using cement, plastics and eggshell mixture (Kshs. 535) is lower than the cost of ceramic tiles (Kshs. 900 t0 1500) available commercially and hence they are affordable for medium and low cost housing.

CHAPTER 5: CONCLUSIONS & RECOMMENDATIONS

5.1 Conclusions

From this study the following conclusions can be made:

[1] Compressive strength of tiles increases with increasing cement content. Compared to plastics and egg shells, cement contributes most significantly to the compressive strength of tiles, which decreases with increasing quantity of plastics. Addition of egg shells does not significantly affect the compressive strength of tiles. Plastics have a tendency to reduce the compressive strength of tiles. Hence, they should be used cautiously.

[2] The presence of plastics seemed to enhance abrasion resistance. The presence of plastics in tiles under study enhanced impact resistance as they resisted impact due to a falling steel ball weighing 438g. Water absorption decreased with increased amounts of cement. However, plastics and egg shells had no significant effect on water absorption of the tiles. The most appropriate mix in the study was that which gave a compressive strength of 17.9 N/mm^2, a water absorption rate of 11.4% as well as tiles that are resistant to impact and abrasion. The density of tiles increased with increase in the quantity of cement. Cement was the major contributing material to density of cubes. The density of cubes decreased with increased plastic quantity. The effect of egg shells and plastics on the density of the cubes was very insignificant.

[3] Economically, the tiles made using cement, plastics and egg shells mixture are affordable (Kshs 535 per m^2) compared to (Kshs. 900 to 1500) for Ceramic tiles available commercially and the production process is cheap since it does not involve more expensive industrial equipment. Wastes (plastics and egg shells) are the major materials that are needed to manufacture of these tiles.

5.2 Recommendations

This research can be very important in conserving the environment most especially in those areas with poor waste disposal facilities by making good use of these wastes in making floor tiles for use in the construction industry.

In this study, the following physical and mechanical properties were not performed on to the tiles, that is: chemical resistance, freeze/thaw resistance, stain resistance, deep abrasion resistance, crazing resistance, thermal shock resistance, Warpage, wedging, bond strength, breaking strength, thermal expansion, and moisture expansion. Therefore, further research should be carried out on the tiles concerning these properties to ascertain their suitability for use in the different environments

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